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Additional groundwater nitrate monitoring sites for Scotland

Groundwater Systems and Water Quality
Integrated Geoscience Surveys (North Britain)
Commissioned Report CR/02/139N

BRITISH GEOLOGICAL SURVEY

COMMISSIONED REPORT CR/02/139N

Additional groundwater nitrate monitoring sites for Scotland

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Key words

Report; Groundwater; Nitrate; Vulnerability Zones; Scotland.

Front cover

One of the existing SEPA monitoring sites in Dumfries and Galloway.

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Foreword

This report is the product of a study by the British Geological Survey (BGS). The work was carried out between October 2001 and March 2002 and funded by SEERAD Agricultural and Biological Research Group Flexible Fund. This report follows on from previous work reported in Ball and MacDonald (2001).

Acknowledgements

Several BGS staff contributed to this study. Much of the fieldwork was undertaken by Roy Fakes, Dr Alastair Matthewson and Charlotte Vye. This was assisted by temporary workers Dr Angela Mudge and Chris McKormick. Dr Alastair Matthewson also provided assistance with databasing. The generous assistance of farmers in providing access to their water supplies for sampling is gratefully acknowledged.

Summary

1. Seventy additional monitoring sites have been identified in the proposed nitrate vulnerable zones in Scotland. The majority of these sites are boreholes and therefore sample deeper groundwater.
2. Two sampling rounds have been completed for these 70 sites.
3. Nineteen percent of the sites have concentrations greater than 50 mg/l, 46% are greater than 25 mg/l. This represents significant and widespread contamination of groundwater in Eastern Scotland, when compared to the low background values and the drinking water standard of 50 mg/l for nitrate.
4. Nitrate data from the additional sites agree closely with the nitrate data collated as part of the main project for identifying potential nitrate vulnerable zones. Additional analysis shows that nitrate concentrations are highest in coincident zones (high risk, high vulnerability areas).
5. The additional monitoring indicates that part of Morayshire (from Forres to Banff) has high nitrate concentrations (40% exceed 25 mg/l and 30% exceed 50 mg/l). These data are similar to other areas already proposed as NVZs. The data suggest that this area should also be an NVZ.
6. Insufficient data are available for the rest of Morayshire and Easter Ross, the Strathmore sub catchment, Falkirk and West Lothian. Sites for drilling monitoring boreholes have been confirmed in Morayshire, Easter Ross and the Strathmore subcatchment. These new boreholes should be drilled and sampled by September 2002. Sites for monitoring boreholes have been identified in West Lothian should funds become available.
7. The Falkirk catchment is, in general, protected from nitrate contamination by a thick covering of clay. This area may not need to be designated as a nitrate vulnerable zone to protect the groundwater.

1 Introduction and scope of report

The Scottish Executive SEERAD Agricultural and Biological Research Group is currently funding work regarding the establishment of Nitrate Vulnerable Zones (NVZs) in Scotland. As part of this effort, the SEPA nitrate monitoring network has being extended to include groundwater sources within many of the proposed NVZ catchments. This report describes the methodology developed for identifying new monitoring sites within the proposed NVZs. The results from the first 2 rounds of sampling are discussed. Each of the regions outlined in the original report (Ball and MacDonald, 2001) are assessed.

2 Methodology for identifying and assessing sites

The main objective of this study was to identify suitable points for groundwater sampling from areas proposed as NVZs, particularly where insufficient data on groundwater nitrate concentrations existed. A programme of work was devised that included an initial desk study phase, followed by a period of reconnaissance fieldwork and initial sampling in November 2001. A further round of sampling took place in February/March 2002 during which a QA assessment of the complete set of sites was undertaken.

The work is discussed in more detail below.

2.1 DESK STUDY

Using BGS databases and geological maps, potential borehole sites were identified that were not already part of the SEPA nitrate monitoring network. Information on recently drilled boreholes was obtained by contacting all known drilling companies working in Scotland. Their information on work completed during 2000 and 2001 helped to update the BGS groundwater database. Boreholes take water from deeper levels within the rocks (generally below 20 m) compared to wells or springs and are therefore less susceptible to local contamination, more indicative of long-term changes in water chemistry and were the preferred source type.

The names and addresses of borehole owners were obtained and a programme of fieldwork developed. A standard form was designed for use in the field which included sections on location, borehole construction, water use, land use and the suitability of the site for monitoring (see Appendix 1). A sketch plan of the site was also included.

2.2 FIELD WORK PHASE

Fieldwork comprised the following:

- Two teams each comprising a BGS staff member and a temporary worker (qualified environmental scientist) were sent to assess potential monitoring sites. The teams covered the whole of the proposed NVZ catchment areas visiting farms, houses and industrial plants that were abstracting groundwater from boreholes, preferably on a regular basis. The work was carried out in November and December 2001. A total of 95 sites were visited.
- The field forms were completed at each site. In particular, the integrity of the source was assessed, the surrounding land use was noted and the ease of access for SEPA staff to take regular samples for nitrate analysis was recorded.

- Water samples were taken where appropriate. Field measurements of pH, conductivity, alkalinity and temperature were taken. A sample was sent to the local SEPA lab and for some sites an additional sample to the BGS lab in Wallingford. At both labs, all major ions were analysed in addition to nitrate.

In general, site owners (mainly farmers) have been helpful in assisting the project. It was clear that most of them had a keen interest in the work and were interested in allowing further sampling to be carried out.

On return to BGS, the data were entered on to a database. In February and March 2002, BGS hydrogeologists (Derek Ball and Alan MacDonald) visited all the sites in order to check the original observations and provide a consistency of judgement as to the suitability of the sites for inclusion in the SEPA network. For most of the sites, a SEPA hydrogeologist or sampler was present to familiarise themselves with the sites and to gain an opinion on the usefulness of each site. A second round of sampling, for nitrate only, was undertaken during this phase of fieldwork.

The database was then updated with the hydrogeologists' comments. A meeting took place on 28 March 2002 between BGS and SEPA staff (D. Ball, A MacDonald, J Burns and J Lees) to discuss the results.

3 A summary of the sites

Ninety-five sites were assessed throughout eastern Scotland. The location of the sites is shown in Figure 1. Seventy-two of the sites were deemed suitable for monitoring groundwater nitrate concentrations. Data were not sought in Aberdeenshire since more than 1000 private water supply sites already exist there (Ball and MacDonald 2001). Since BGS had recently completed a groundwater chemistry assessment for the main aquifer in the Nith valley (MacDonald et al. 2000), it was excluded to leave more resources available for the rest of Scotland. The distribution of the sites and data are discussed in more detail in the following chapters. A full list of the sites is given in Appendix 2.

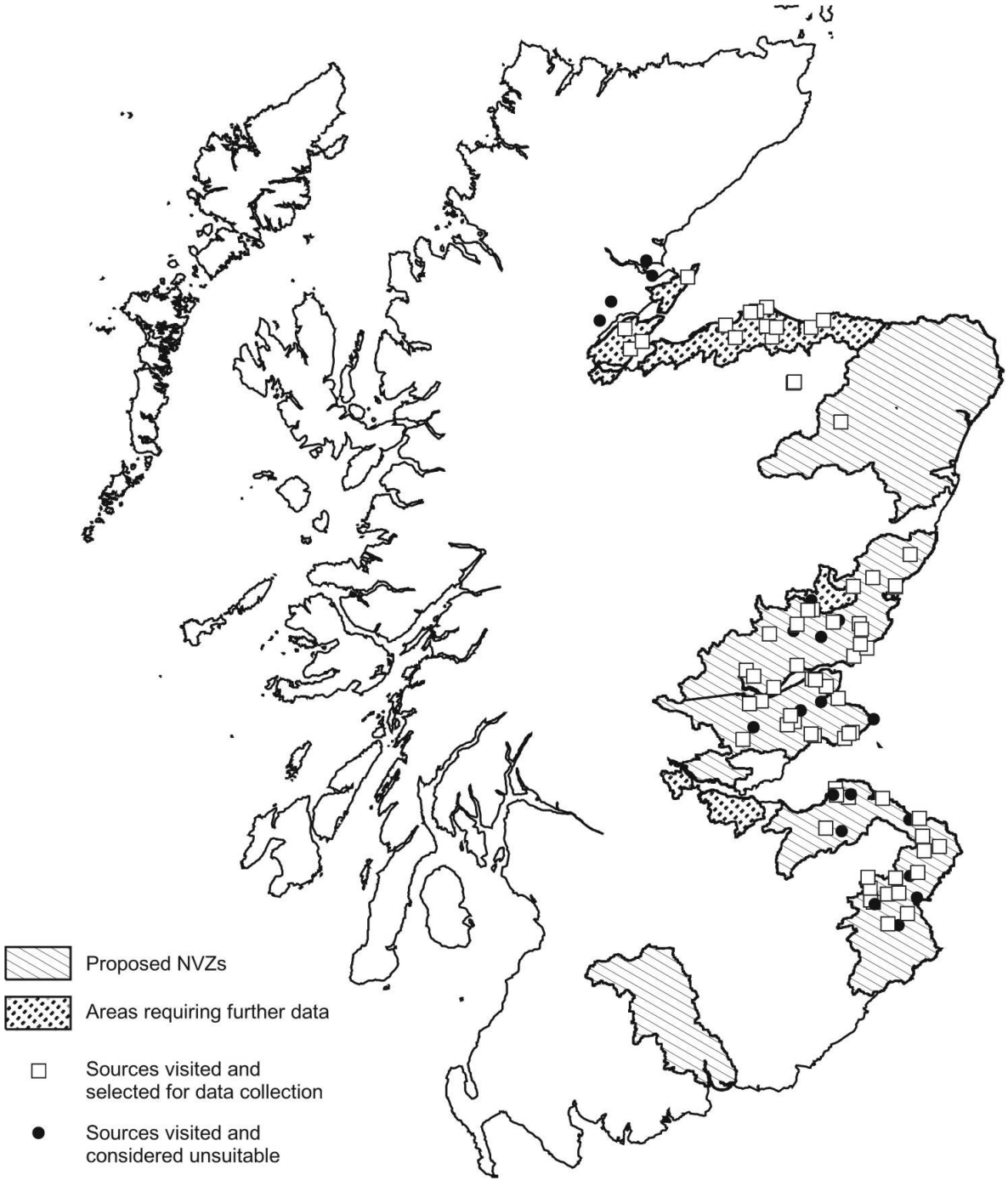

Figure 1 Location of sites assessed during the project. The NVZ areas are taken from Scottish Executive (2002).

Of the 72 sites, 56 are within the proposed NVZ areas, and 14 in the areas marked as requiring additional data (Figure 1). Unfortunately there is a lack of reliable boreholes for monitoring in parts of Scotland where more data are required. In these areas, purpose drilled monitoring boreholes are required to accurately assess nitrate concentrations. Two of the sites are outwith the NVZ areas, but have been included since they may give valuable information about point contamination in upland areas.

The data collection has been biased towards boreholes. Sixty-six of the sites are boreholes, with four wells and two springs. In general this ensures that the sampled water is deeper groundwater, and less susceptible to point contamination. Priority was given to sites that are used on a regular basis. High pumping rates average out nitrate concentrations over a large area and can therefore be more representative of regional conditions.

The majority of the sites are surrounded by agricultural land. However, five golf courses, one forest area and one purely urban area have also been included. Over half of the sites (38) are located in areas with a high risk of nitrate leaching (very high, high or moderately high as defined by the Macaulay Institute (Lilly et al. 2001).

4 Nitrate concentrations for the sites

Two rounds of sampling have taken place for the approved sites by the time of this report (April 2002). Nitrate will continue to be monitored at these sites quarterly by SEPA. This chapter gives an interpretation of the nitrate data collected to date. All nitrate concentrations are quoted as nitrate, for comparison with the drinking water standard of 50 mg/l.

4.1 SAMPLING ISSUES

SEPA laboratories analyse for nitrate by taking a one litre unfiltered sample of water. This is generally acceptable if the samples are air tight, kept at a low temperature (4 °C) and out of direct sunlight. However, by not filtering the samples, organic material can be present leading to denitrification of the sample. This can in turn produce an *underestimate* of the nitrate present in the groundwater. To minimise this problem, samples must be analysed as soon as possible after sampling. In practice it is usually possible to analyse within 24 hours.

However, for the first round of samples (carried out by BGS) it was only possible to take samples to SEPA laboratories twice weekly. Therefore, to act as a back up, BGS took separate filtered samples at most of the sites and sent them for analysis at BGS's own laboratory in Wallingford. In the second round of sampling, SEPA personnel came out in the field with BGS, and samples could therefore be returned to the SEPA laboratories and analysed within 24 hours. Separate filtered samples were therefore not required.

Figure 2 shows the nitrate concentrations at 62 sites where the nitrate was measured in both November 2001 and March 2002. There is an apparent increase nitrate from November 2001 to March 2002. However, further analysis of the data and comparison with the filtered analysis carried out at the BGS laboratory demonstrates that this increase is in fact due to denitrification of the November 2001 samples (Figure 3). All the data for each site are shown in the Appendix.

To minimise the errors caused by the delay in analysing the unfiltered November samples, the March 2002 data are taken as most representative of the site. Where a March 2002 sample is not available, the November 2001 filtered sample is taken. Lastly, if nothing else is available, the November 2001 unfiltered estimate of nitrate is used.

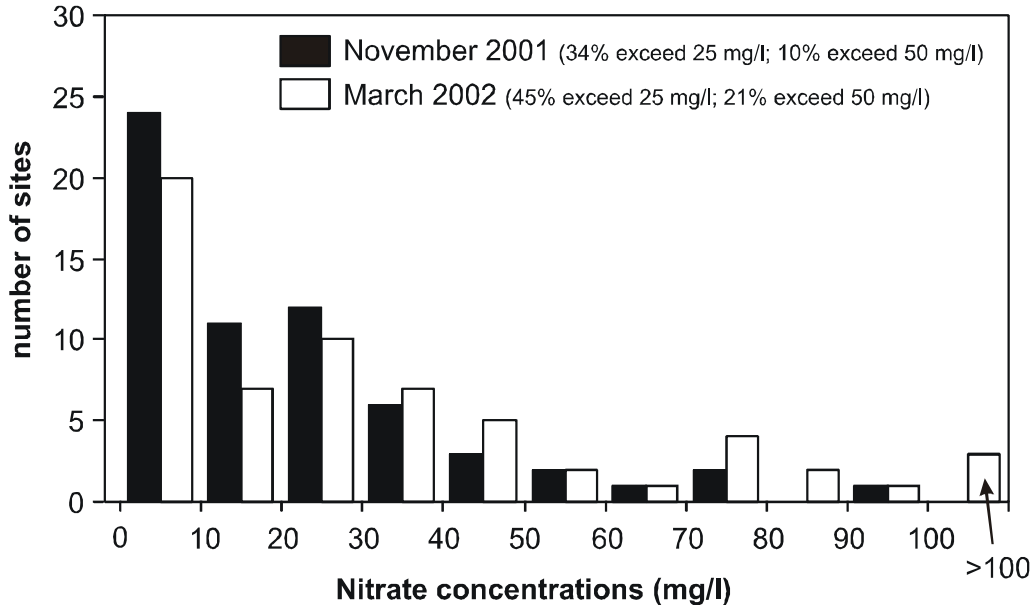

Figure 2 Histogram of nitrate concentrations at sites where nitrate was measured in November 2001 and March 2002. The samples are both unfiltered.

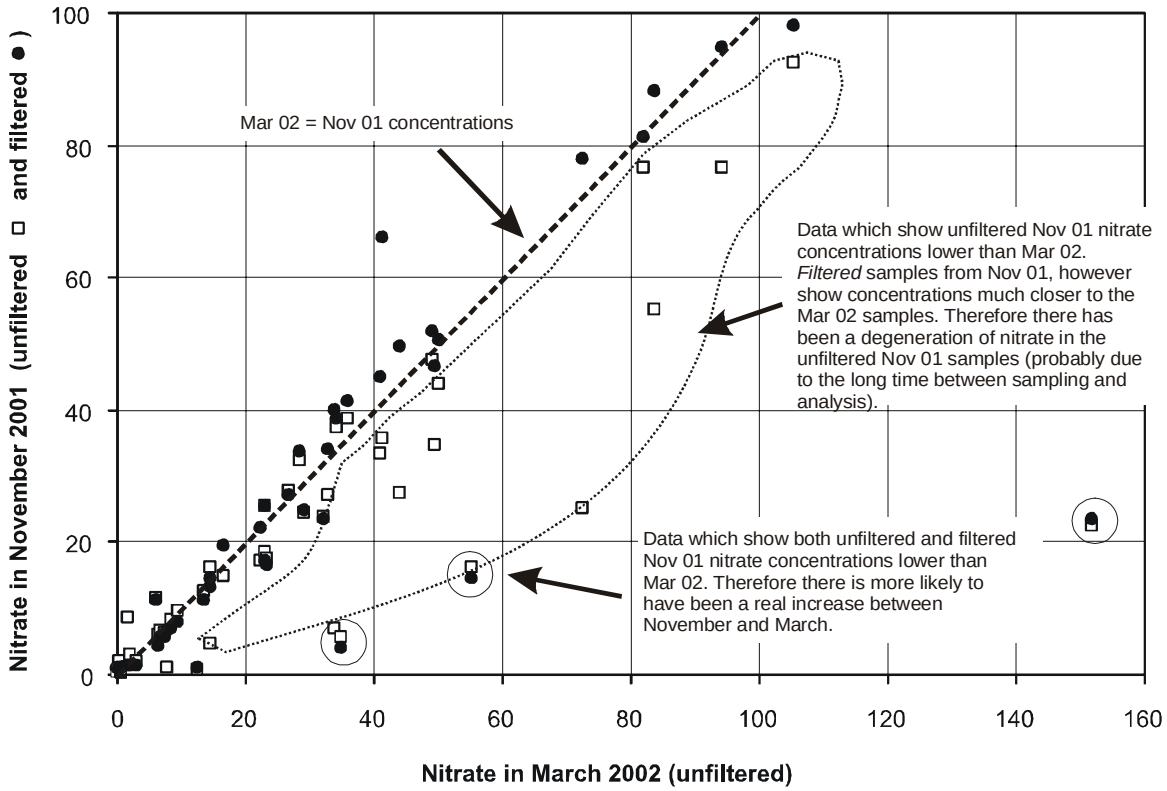

Figure 3 Comparison between nitrate concentrations measured from filtered and unfiltered samples in November 2001 and unfiltered samples in March 2002. Note that several of the unfiltered samples in November 2001 are artificially low due to denitrification in the period between sampling and analysis.

4.2 NITRATE CONCENTRATIONS

For the 70 sites within the proposed NVZ areas (and those marked as requiring additional data), 19% of the sites have concentrations greater than 50 mg/l; 46% are greater than 25 mg/l. This indicates significant contamination of groundwater within the proposed NVZ areas. A summary of the data is given in Table 1. The statistics are similar to those for the existing data for the NVZ areas summarised in Ball and MacDonald 2001 (Table 1). This is encouraging and supports the assertion that although not ideal monitoring sites, the existing private water supply data can be informative when used at a broad scale, primarily because of the large number of sites sampled.

Table 1 Summary of nitrate data for the proposed NVZ areas.

Dataset	Number of sites	Sites > 50 mg/l	Sites > 25 mg/l
New sites in nitrate vulnerable zone areas	70	19%	46%
Sites in coincident zones*	28	21%	50%
Sites outwith coincident zones*	44	16%	41%
Existing data in NVZs (from Ball & MacDonald 2001)	2137	25%	-

* coincident zones are areas where high nitrate leaching potential overlies vulnerable aquifers.

The new nitrate monitoring sites also indicate higher nitrate concentrations in coincident zones (see Table 1). The coincident zones are where the most vulnerable aquifers are at the highest risk of nitrate leaching. However, groundwater nitrate concentrations are still high within the proposed NVZ areas, away from the coincident zones. Further analysis of the data showed that the high nitrate away from coincident zones is primarily in aquifers classed as highly vulnerable.

A map of the nitrate data for the new monitoring sites is shown in Figure 4. Data for the new and existing monitoring sites are shown in Figure 5. The distribution of data, and implications for NVZ designation will be discussed in the next two sections.

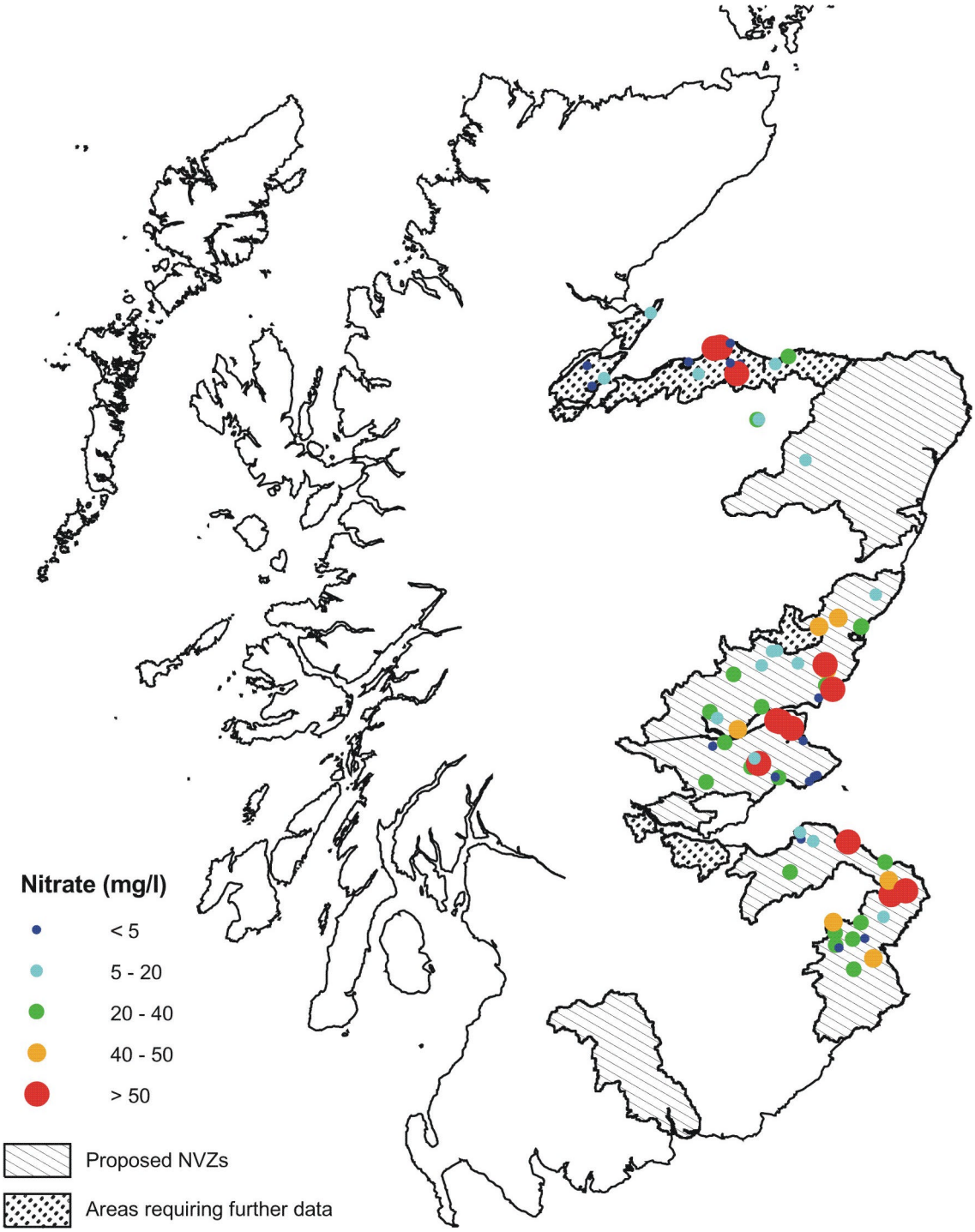

Figure 4 Nitrate concentrations from the 72 new monitoring sites in Scotland.

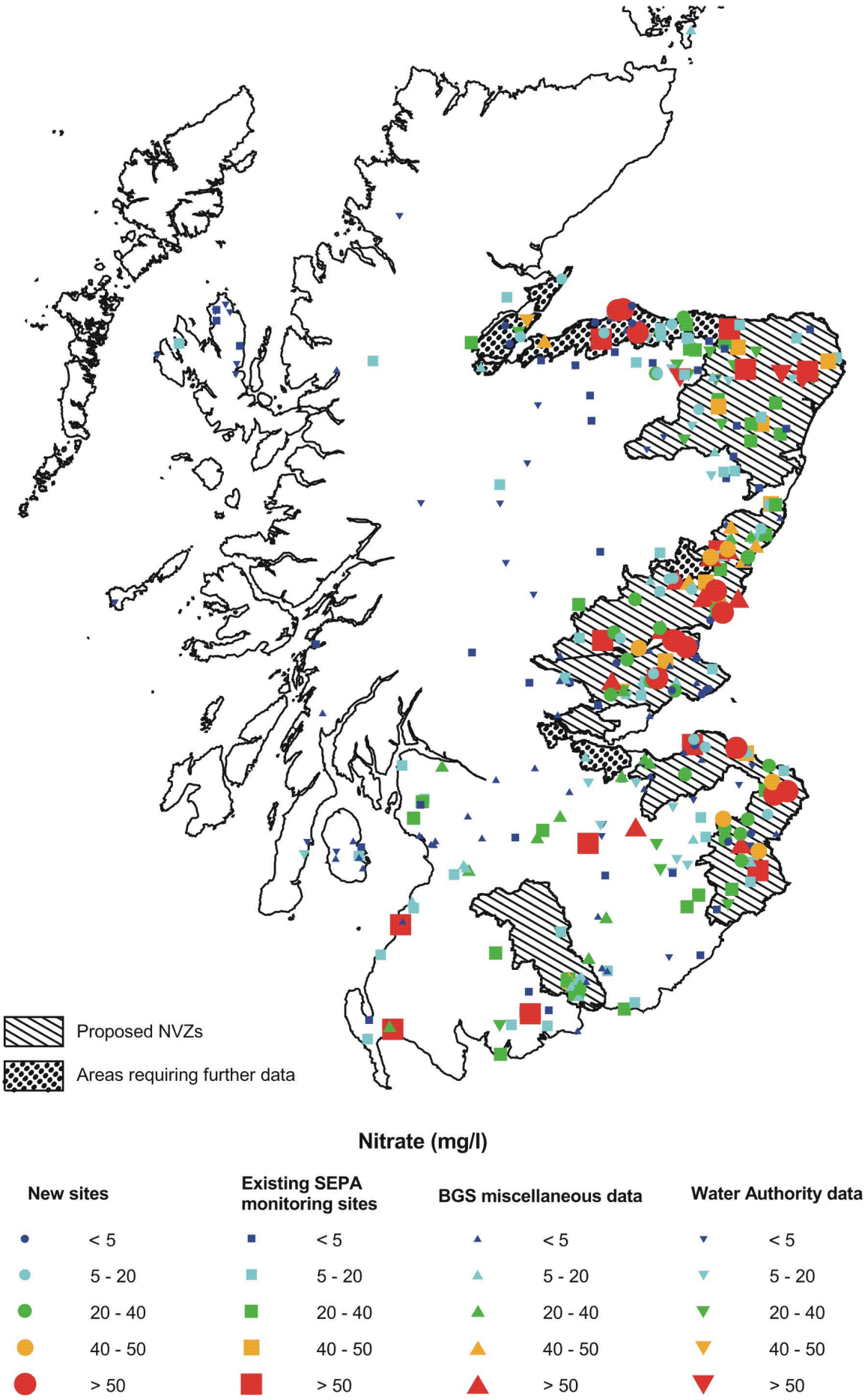

Figure 5 Nitrate concentrations for the new and existing monitoring sites in Scotland (excluding private water supply data).

5 Areas requiring further data ('Blue areas')

The 'blue' areas are those parts of Scotland identified by the Scottish Executive (2002) as requiring further data collection before being proposed as NVZs (see Figure 1) and coloured blue in the consultation document. Due to the compressed time frame of the NVZ research, much of the field work for identifying good new monitoring points had already been carried out before the blue areas had been finalised and published. However, data were sought for the four 'blue' areas as part of the programme of finding new monitoring points – particular attention being given to Morayshire and Easter Ross.

5.1 MORAYSHIRE AND EASTER ROSS

Fourteen new monitoring sites were identified for Morayshire and Easter Ross (Figure 4). Four sites (29%) exceed 25 mg/l and three sites (21%) exceed 50 mg/l. The data indicate that groundwater in much of the area is significantly contaminated.

However, the distribution of nitrate data across the area is highly biased (see Figure 5) with most of the data being available between Forres and Banff. There are 10 new sites in this area, including three that exceed 50 mg/l. Further analysis shows that three of the sites recording low nitrate concentrations are not agricultural, but represent a golf course, an urban area (Elgin swimming pool) and a residential zone. The existing SEPA nitrate monitoring network sites between Forres and Banff also indicate high nitrate (even allowing for the exclusion of the high nitrate SEPA site at Forres which is a shallow polluted source).

The new results and the SEPA data between Forres and Banff indicate general groundwater contamination in the area. The data show similar trends to those evident in other NVZ areas. There is strong evidence, therefore, for including the area from Forres to Banff as a Nitrate Vulnerable Zone.

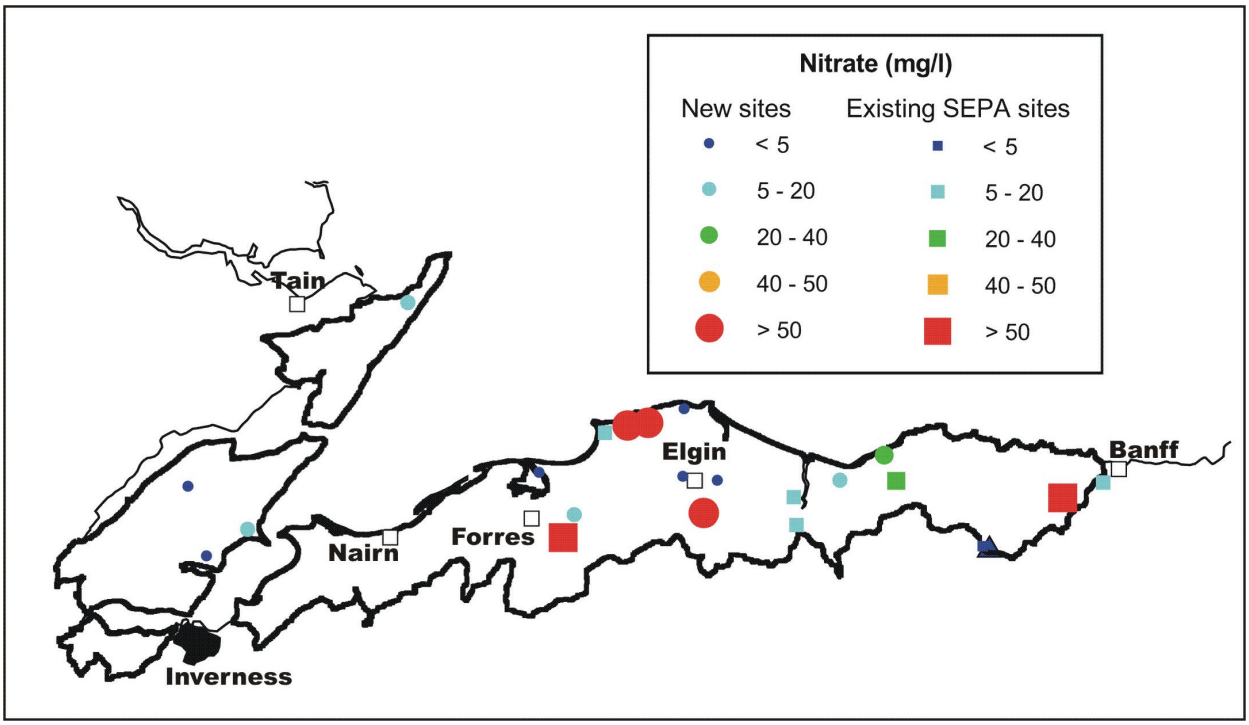

Figure 6 Nitrate concentrations for the new and existing monitoring sites in Morayshire and Easter Ross.

There are few data available between Forres and Inverness and then north of Inverness to Tain. The few samples taken on the Black Isle indicate low nitrate, although these were not targeted on intensive agricultural areas, which are present only in small pockets at the coast. The Black Isle is different compared to the area near Tain. The former includes a large proportion of wooded land, with steep slopes. The latter is low-lying and contains widespread intensive arable faming. Currently, there are insufficient data available in these areas to recommend designation as nitrate vulnerable zones. Additional information is required. This can be achieved by the drilling of purpose-designed monitoring boreholes. The fieldwork phase of this project included the identification of sites for drilling and 6 sites have been have been confirmed in these areas. Two of the sites are near Tain and the remaining 4 are between Inverness and Forres. The completion of these boreholes will provide a good basis for an effective monitoring network along this coast. Drilling and sampling should be completed by September 2002.

5.2 STRATHMORE

Although data were sought in this area, which includes the catchment of the River South Esk between Forfar and Brechin, no suitable boreholes were found for sampling. As land use is similar to the rest of Strathmore, it is expected that nitrate concentrations will be similar and contain significant concentrations of nitrate. The construction of 2 or 3 monitoring boreholes should confirm this, and access to suitable sites has already been agreed with local farmers. Samples should be available by September 2002.

5.3 FALKIRK

No extra monitoring sites were found within the Falkirk area. However, this small catchment is almost entirely underlain by layers of marine clay over 20 m thick in places (MacDonald et al. 2002). Data from BGS archives and maps indicate that the clay should form an effective barrier and protect deep sandstone aquifers in the Carboniferous rocks. Therefore, groundwater in this small catchment is unlikely to be at risk from nitrate contamination.

5.4 WEST LOTHIAN

No monitoring sites were found within the part of West Lothian included in the NVZ designation. There exists in the area a good mains water supply network and so the requirement for private water supplies is lacking. However, the catchment contains significant agricultural activity including several chicken farms. There is, therefore, the potential for widespread groundwater contamination. Some preliminary work has been carried out to identify sites for constructing monitoring boreholes, but current drilling funds are being targeted towards the Moray coast and Strathmore. If funds are available, drilling should be undertaken in West Lothian.

6 Proposed NVZ areas

Most of the new monitoring sites (56) are located in the proposed nitrate vulnerable zones. The rationale for this was twofold: (1) to provide good quality data to help with designation and (2) to form a basis for long term monitoring of nitrate concentrations within the nitrate vulnerable zones. The different areas described in Scottish Executive (2002) will be discussed.

6.1 ABERDEENSHIRE

Aberdeenshire was not targeted for extra monitoring sites at this stage. The Aberdeenshire NVZ already has 24 SEPA monitoring points within it, more than double that of any of the other proposed NVZs. There are also more than 1000 sites where nitrate had been monitored at private water supplies. Within the short time frame of this study it was not possible to identify new monitoring sites in all areas, therefore Aberdeenshire was omitted.

6.2 STRATHMORE

A further 20 monitoring sites were identified within the Strathmore area (see Figure 4). Twelve sites (60%) exceeded 25 mg/l and three sites (15%) exceeded 50 mg/l. This additional monitoring is consistent with the data presented in Ball and MacDonald (2001) and indicates significant and widespread contamination of groundwater in Strathmore. The results reinforce the inclusion of much of Strathmore within NVZs.

6.3 FIFE

Sixteen additional nitrate monitoring points were identified in the Fife NVZ. Seven sites (44%) exceeded 25 mg/l and four sites (25%) 50 mg/l nitrate. This additional monitoring is consistent with the data presented in Ball and MacDonald (2001) and adds further evidence to the previous conclusion that significant and widespread contamination of groundwater is present throughout Fife. Of particular interest was a cluster of high nitrate sites in northeast Fife close to disposal zones for poultry slurry. These results, along with those from other parts of Scotland, demonstrate the high potential for point source pollution from animal wastes.

6.4 LOTHIANS AND BORDERS

Nineteen additional monitoring sites were identified in Midlothian, East Lothian and the Borders. Nine sites (47%) exceeded 25 mg/l and three sites (19%) exceeded 50 mg/l nitrate. The results indicate widespread nitrate contamination, consistent with that reported in Ball and MacDonald (2001).

Of note is the occasional low nitrate concentration in areas where high nitrate is expected. These tend to be in sites that are not pumped on a regular basis. A possible explanation for such low results is that the groundwater abstracted from these sites is relatively old (pre 1950s) compared to that from nearby shallow sources. By measuring the age of the groundwater the reasons for the discrepancy may become clearer.

6.5 NITHSDALE

No searches were carried out for additional monitoring sites in Nithsdale as the main fieldwork phase of the project had been completed before this catchment was proposed as a nitrate vulnerable zone. The original data showed that nitrate concentrations are high, with 29 sites

(21%) exceeding 50 mg/l. A recent report by MacDonald et al. (2000) included the results of nitrate analyses from 21 boreholes in the main aquifer in Nithsdale. Of these sites, 57% exceeded 25 mg/l and 5% exceeded 50 mg/l. A rising trend in nitrate concentration was also identified, and indicated that the average nitrate concentration of water recharging the aquifer was 40-50 mg/l. Some of the boreholes used in this work could be included in the existing SEPA nitrate monitoring network. In addition, an ongoing project funded by BGS and Scottish Water involves the drilling of 10 monitoring boreholes within the main Permian aquifer at Dumfries and these will be available for measuring nitrate concentrations during 2002.

7 Further monitoring

During the second round of sampling, carried out during March, SEPA staff accompanied BGS on site visits. For further sample rounds, SEPA staff are now familiar with the owners, locations and individual sampling requirements for most of the new monitoring sources. The sites have been approved by SEPA and will be monitored until September 2002 (giving a full years sampling). Most of the sites will then be incorporated into the existing SEPA network. However this awaits formal agreement from SEPA, which is likely to take place at a review meeting in September 2002.

Over 90% of the sites for new drilling have also been inspected by SEPA and they have given their approval for inclusion in the network. Health and safety issues are significant at the new sites in Morayshire, as they are located close to the A96, the main trunk road in the area. Once construction of the boreholes is complete, SEPA will adopt the sites into their regular sampling programme. Portable sampling pumps will be used to flush out standing water and take representative samples.

The 72 new monitoring sites have been rigorously validated and are considered representative of the groundwater conditions within each catchment. In addition to the chemical data already being collected, it may be feasible to gain further information for many of the sites on such factors as the age of the groundwater and the variation in chemical characteristics at different depths within the boreholes. This work would be a useful aid in interpreting the nitrate results, the future efficacy of action programme measures and in helping to understand more fully the processes at work within aquifers.

8 Summary and recommendations

During November 2001 a total of 95 sites were assessed throughout Eastern Scotland for their suitability as nitrate monitoring sites. Of these, 72 were considered to be suitable for inclusion in the SEPA monitoring network. The sites were resampled in March 2002. All the information collected on the sites was captured on a Microsoft Access database. This database has been handed over to SEPA. In general, site owners have been helpful is assisting the project and were interested in allowing further sampling to be carried out.

A summary of the results from the new monitoring sites is given below.

- 56 of the sites are located within proposed NVZ areas. A further 14 are within catchments for which additional data was required. Two are located outside the NVZ proposed areas in an upland catchment.
- Of the 70 sites located in the proposed NVZ areas, 19% have nitrate concentrations greater than 50 mg/l and 46% greater than 25 mg/l.
- Additional data collected in Morayshire from Forres to Banff indicates 4 sites (40%) exceeding 25 mg/l and 3 sites (30%) exceeding 50 mg/l.
- Nitrate data from the additional sites agree closely with the nitrate data collated as part of the main project for identifying potential nitrate vulnerable zones. Additional analysis shows that nitrate concentrations are highest in coincident zones (high risk, high vulnerability areas).

Implications for NVZ designation.

- Results from the 70 sites reinforce the case for the establishment of NVZs in the Borders, Fife and Strathmore areas.
- Additional data for Morayshire indicate that the area from Forres to Banff should also be designated as an NVZ.
- There are insufficient data for the rest of the Morayshire/Easter Ross area (i.e. between Forres and Inverness and northward to Tain), the Strathmore subcatchment, the Falkirk subcatchment and West Lothian area to support their designation as NVZs.
- Thick clay under the Falkirk catchment is considered by BGS to be sufficient reason to exclude this area from designation.

Recommendations and future work

- Sites have been confirmed and drilling contracts let for the drilling of additional monitoring boreholes in Easter Ross, Morayshire and the Strathmore sub-catchment. Sites in West Lothian have been identified should additional funds be made available.
- The 72 sites will be sampled twice by SEPA before September 2002. It is envisaged that most will then be incorporated into their monitoring network.
- SEPA's existing monitoring network should be assessed using the same methodology as used for this report.
- The results of the first sampling round in November highlighted the problem of denitrification of unfiltered samples. This demonstrates the importance of applying strict and consistent sampling procedures and in particular having nitrate measured within 24 hours of sampling.

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Appendix 1 Field form for recording information about monitoring sites

Additional Nitrate Monitoring Network 2001

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Field assessors ..... Date .....

..... Time .....

Site Details

Site name		BGS No.
NGR		
Name	Address	
Tel		
Land Use	Agricult / Industr / Residential / Golf Course / Other (specify)	
Mapped Geology	Solid	Drift
BGS aquifer class	MLURI nitrate leaching class	

Source Details

Source type (tick)

Spring ☐
Well ☐
Borehole ☐
Other ☐
.....

Use (tick, circle dominant)

Domestic ☐
Irrigation ☐
Livestock ☐
Industrial ☐
Other ☐
.....

Drilling details

Company .....

Date .....

Location of records .....

Reason for drilling .....

.....

Ref

Additional Nitrate Monitoring Network 2001

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Source Construction & Location

Depth	Diameter	Prate	Seasonality
Casing\screen type and depth			Seal around top of source
Immediate surroundings (10 m)		Surrounding land use – potential contamination	

Sampling

Sampling point closest to source
Access
Equipment necessary
Upgrading required

Samples

Sample ID **SN /**	Additional comments about samples
Date	
Conductivity	
PH	
Temperature	
Alkalinity	

Ref

Site map and potential pollution sources

Ref

Additional Nitrate Monitoring Network 2001

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Summary

Source type		Well, borehole, spring, other....
Aquifer class		Drift or Solid; high, moderate or weak permeability
MLURI class		Nitrate leaching potential
Source integrity		1 = no possibility of surface contamination or point sources in 10 m; 2 = little possibility of surface contamination; 3 = likely surface contamination or point sources in 10 m.
Point Nitrate sources		(1 = none 2 = some 3 = many)
Diffuse Nitrate sources		(1 = none 2 = some 3 = many)
Sample Point		1 = at wellhead 2 = tap far from borehole 3 = after tank (unaerated) 4 = after tank aerated)
Access		(1 = Good 2 = Moderate 3 = Poor)
Upgrading Required		

Ref

Appendix 2 Summary of sites assessed

ID	Site Name	Easting	Northing	Land use	Seasonality	Source	Aquifer vulnerability	Nitrate leaching	Assess-ment
1	West Fortune Farm	353100	678900	Agricultural	Soon to by year round	Borehole	LL	VH	In
2	Gullane Golf Club	348100	682200	Golf Course	Summer Only	Borehole	HH		In
3	Luffness Mains Farm	348500	679600	Agricultural	Summer Only	Borehole	HL	VH	In
4	Aberlady Mains Farm	347352	679777	Agricultural	Summer Only	Borehole	HL		Out
5	Congalton (Toll Field)	354320	680024	Agricultural	Summer Only	Borehole	LH	VH	Reserve
6	Marvington Farm	350651	665636	Domestic	Year round	Spring	HL	H	Out
7	Belhaven Brewery	366500	678400	Industrial/ Agricultural	Year round	Borehole	HH		In
8	West Reston Mains Farm	388692	659509	Agricultural	Year round	Spring	MN		In
9	Bowmont Forest Saw Mill	372936	628861	Industrial/ Forest	Year round	Borehole	HL		Out
10	Windywalls Farm	376213	633408	Agricultural	Year round	Borehole	LL	M	In
11	Roxburghe Mains Farm	368737	629328	Domestic/ Agricultural	Year round	Borehole	HL	M	In
12	Covehouse Farm	363021	637815	Agricultural	Year round	Well	HH		In
13	Yarlside Farm	361823	638669	Livestock	Year round	Borehole	HL	M	In
14	Falsidehill Farm	368435	640865	Livestock	Year round	Borehole	HL	M	In
15	Lintlaw Farm	382889	657956	Agricultural	Year round	Borehole	HL	M	In
16	Brockholes Farm	382122	663606	Agricultural	Year round	Borehole	LN		In
17	Fogorig Farm	377406	648125	Agricultural	Year round	Borehole	ML	M	Out
18	Whitsome Farm	380280	649516	Agricultural	Year round	Borehole	ML	M	In
19	Homebank Farm	380117	639606	Agricultural	unknown	Borehole	ML	H	Out
20	Kennetsideheads Farm	372930	641297	Agricultural	Year round	Borehole	ML	M	In
21	Girnick Farm	363553	637015	Agricultural	Year round	Well	HL	M	Out
22	Upper Huntleywood	361639	643201	Agricultural	Year round	Borehole	HL		In
23	Hyndsidehill Farm	360741	647517	Agricultural	Year round	Borehole	HL		In
24	Flourish Walls	371545	647209	Agricultural	Year round	Well	HL		In
25	Neuk Farm	377085	670081	Agricultural	Year round	Borehole	HH	M	Reserve
26	Drysdale Quarry	380872	670531	Agro Industry	Year round	Borehole	LN		In
27	Glenkinchie Distillery	344300	666700	Industrial/Agricultural	Year round	Spring	MH	M	In
28	Pauls Malt Ltd	355204	734046	Industrial	Year round	Borehole	HH		In

ID	Site Name	Easting	Northing	Land use	Seasonality	Source	Aquifer vulnerability	Nitrate leaching	Assess-ment
29	Caledonian Water Waste Water Treatment Plant	360480	737297	Industrial/ Agricultural	Year round	Borehole	HM		In
30	West Balmirmer Farm	357894	738705	Agricultural	Summer Only	Borehole	HL	M	In
31	North Mains Connonsythe	357486	746878	Agricultural	Summer Only	Borehole	HL	M	In
32	Grange of Conon Farm	358235	744692	Agricultural	Summer Only	Borehole	HL	M	In
33	West Lournrie Farm	349720	748198	Agricultural	Summer Only	Borehole	HL		Reserve
34	Ladenford Farm	347155	747381	Agricultural	Year round	Borehole	HL	M	In
35	Charleton Hillside	371559	761117	Agricultural	Summer Only	Borehole	HH	H	In
36	Barflat Farm	350147	825860	Agricultural	Year round	Borehole	ML		In
37	Robbie Dhu Well, Glenfiddich Distillery	331505	841132	Industrial/ Agricultural	Year round	Well	LH		In
38	Borehole BVWA7BOR01, Glenfiddich Distillery	332064	841514	Industrial/Agricultural	Year round	Borehole	LH		In
39	Longmorn Farm	323375	859074	Agricultural	Year round	Borehole	HH	M	In
40	Moray Golf Club	321187	870799	Golf Course	Summer Only	Borehole	HH		In
41	Duffus House (The Old Manse)	317495	868416	Agricultural	n/a	Well	HH	VH	Out
42	Burnside Farm	317143	869173	Agricultural	Year round	Borehole	HH	VH	In
43	Moray Leisure Centre	321042	863236	Urban	Year round	Borehole	HH		In
44	Windsoer Farm	338555	862798	Agricultural	Year round	Borehole	ML	M	In
45	The Findhorn Foundation	305018	863658	Residential	Summer Only	Borehole	MH		In
46	Blackhillock Farm	308901	858920	Agricultural	Year round	Borehole	LL	M	In
47	Kirkhill Farm	324930	862790	Agricultural	Year round	Borehole	HH	H	In
48	Weddershill Farm	314798	868833	Agricultural	Year round	Borehole	HL	VH	In
49	Corrachie Farm	267863	854372	Agricultural	Year round	Well	ML		In
50	Viewmount	272399	857319	Agricultural	Year round	Borehole	MN		In
51	Woodlea House	265756	862152	Forest	Irregular	Borehole	ML		In
52	Petley Farm	290346	882591	Agricultural	Year round	Borehole	MH	H	In
53	Glenmorangie Distillery	276502	883127	Industrial/Forest	Year round	Spring	ML		Out
54	Skibo Castle	274207	889007	Residential/Golf Course	Year round	Borehole	MH		Out
55	Wester Lealty Farm	260515	873044	Agricultural	Year round	Borehole	ML		Out
56	Swordale	256128	865594	Agricultural/Forestry	Year round	Borehole	ML		Out

ID	Site Name	Easting	Northing	Land use	Seasonality	Source	Aquifer vulnerability	Nitrate leaching	Assess-ment
57	Pauls Malt Ltd, Buckie Maltings	343512	865514	Industrial/Agricultural	Year round	Borehole	LL		In
58	Balmalcolm Farm	331995	708589	Agricultural/ Agroindustry	Year Round	Borehole	HH	VH	In
59	Orkie Farm, Main Borehole	329163	707327	Agricultural/Agroindustry	Year Round	Borehole	HH	H	In
60	Orkie Farm, Borehole 2	329215	707173	Agricultural/ Agroindustry	Year Round	Borehole	HH	H	In
61	St Andrews Golf Links BH2	349196	717616	Golf Course	Summer Generally	Borehole	MM	VH	In
62	Bowhouse Farm (Abercrombie Farm)	351610	701898	Agricultural	Summer Only	Borehole	MH	VH	In
63	Easter Grangemuir Farm	354648	704154	Agricultural	Summer Only	Borehole	MH	H	In
64	Inch Farm	353421	703752	Agricultural	Variable-as & when needed	Borehole	MH	M	In
65	Pilmuir Farm	339828	703084	Agricultural	Summer Only	Borehole	MH	M	In
66	Bankhead Farm	338540	703551	Agricultural	Summer Only	Borehole	ML	M	In
67	Hilton of Carslogie Farm Borehole 1	334540	712961	Agricultural	Summer Only	Borehole	HL	M	Out
68	Hilton of Carslogie Farm Borehole 2	334540	712961	Agricultural	Summer Only	Borehole	HL	M	Out
69	Ladybank Golf Club	330419	710870	Golf Course	Summer Only	Borehole	HH		In
70	Kinnaird Farm	342582	716313	Forest	Year round	Spring	HN		Out
71	Loch Leven Mills	311853	701433	Industrial	Year round	Borehole	HL	M	In
72	Wester Gospetry Farm	316200	706342	Agricultural	Summer Only	Borehole	HL	M	Reserve
73	Balcomie Golf Course	363197	709483	Golf Course	Summer Only.	Borehole	MH	M	Out
74	Newton Hill Quarry (Sand and Gravel)	341179	724365	Industrial (Water removal)	all year round	Pond	LH		Out
75	St Michaels Golf Course	344531	722202	Golf Course/ Agriculture	Summer Only	Borehole	LH		In
76	Wormit Farm (Farmers: J & D Henderson)	338922	725141	Agricultural	Year Round	Borehole	LN	M	In
77	Newton Hill Farm	340165	724750	Agricultural, Irrigation	Mainly Summer	Borehole	LH		In
78	WCF Farm Produce	319053	716642	Agricultural/ Agroindustry	Year Round	Borehole	HH		In
79	Balmanno Farm	314388	715465	Agricultural	Year Round	Borehole	LL		In
80	Star Inn Farm	333155	730575	Agricultural	Year Round	Borehole	HL	VH	In
81	Kirriemuir Golf Course	338886	756108	Golf Course	Summer & Autumn	Borehole	HL		Reserve
82	Logie House	339160	752276	Agricultural	Year Round	Borehole	HH	M	In

ID	Site Name	Easting	Northing	Land use	Seasonality	Source	Aquifer vulnerability	Nitrate leaching	Assess-ment
83	Pluckerston Farm	337315	752168	Agricultural	Summer only	Borehole	HL		In
84	Mains of Errol	323964	721856	Agricultural	Year Round	Borehole	LL	VH	In
85	Kirkton of Nevay	331913	744126	Agricultural	Occasional use	Borehole	HH	M	Out
86	Nether Finlarg	342599	741800	Agricultural	n/a (not used at present)	Borehole	HL		Reserve
87	Castleton of Eassie Farm	333107	746597	Agricultural	n/a (not used at present)	Borehole	HL	M	In
88	Scones of Lethendy	313247	728664	Agricultural	Summer mainly	Borehole	HL	M	In
89	Murrayshall Golf Club	316088	726208	Agricultural	Summer & Autumn	Borehole	LL		In
90	Findowrie Farm	355165	761376	Agricultural	Year Round	Borehole	LL		In
91	Coupar Grange Farm	322357	742876	Agricultural	Year Round	Borehole	LH		In
92	Stracathro Hospital	362667	764803	Hospital/ Agriculture	Year Round	Borehole	LL		In
93	Davo Mains Farm	377248	773828	Agricultural	Year Round	Borehole	HL		In
94	Pauls Malt Ltd BH1	371705	761422	Industrial/ Agricultural	Year Round	Borehole	HM		In
95	Pauls Malt Ltd BH2	371686	761625	Industrial/ Agricultural	Year Round	Borehole	HH		In

Appendix 3 Nitrate (mg/l) results for monitoring sites

ID	Site Name	Nov 2001 SEPA (unfiltered)	Nov 2001 BGS (filtered)	Mar 2002 SEPA (unfiltered)
1	West Fortune Farm	11.7	11.1	6.1
2	Gullane Golf Club	0.7	0.9	12.7
3	Luffness Mains Farm	0.4	0.9	0.7
7	Belhaven Brewery	5.6		74.4
8	West Reston Mains Farm	43.8		72.6
10	Windywalls Farm	27.7	49.6	44.0
11	Roxburghe Mains Farm	17.5	16.4	23.4
12	Covehouse Farm	4.8		4.8
13	Yarlside Farm	32.4	33.7	28.3
14	Falsidehill Farm	32.3		
15	Lintlaw Farm	27.6		122.2
16	Brockholes Farm	35.0	46.5	49.6
18	Whitsome Farm	15.1	19.5	16.5
20	Kennetsideheads Farm	0.6	0.9	0.7
22	Upper Huntleywood	18.7	17.3	22.9
23	Hyndsidehill Farm	33.6	44.7	41.0
24	Flourish Walls	20.1		23.6
26	Drysdale Quarry	21.0		39.2
27	Glenkinchie Distillery	23.7		22.8
28	Pauls Malt Ltd	2.1	1.3	3.1
29	Caledonian Water Waste Water Treatment Plant	16.4	14.6	55.2
30	West Balmirmer Farm	25.7	25.3	23.2
31	North Mains Connonsythe	61.1		70.4
32	Grange of Conon Farm	45.6	47.0	
34	Ladenford Farm	12.5	11.1	13.6
35	Charleton Hillside	39.0	41.2	36.0
36	Barflat Farm	20.7	19.5	
37	Robbie Dhu Well, Glenfiddich Distillery	22.8		24.2
38	Borehole BVWA7BOR01, Glenfiddich Distillery	15.9		15.8
39	Longmorn Farm	93.0	97.9	105.4
40	Moray Golf Club	5.3	4.9	
42	Burnside Farm	51.4		64.6
43	Moray Leisure Centre	2.9	1.3	2.2
44	Windsoer Farm	6.4	5.8	7.6
45	The Findhorn Foundation			1.2
46	Blackhillock Farm	15.2		13.4
47	Kirkhill Farm	0.4	0.9	0.1
48	Weddershill Farm	55.4	88.2	83.7
49	Corrachie Farm	1.9	0.9	0.4
50	Viewmount	5.8	4.4	6.5
51	Woodlea House	8.6	1.3	1.5
52	Petley Farm	0.9	6.6	7.8
57	Pauls Malt Ltd, Buckie Maltings			26.1
58	Balmalcolm Farm	25.2	78.0	72.6

ID	Site Name	Nov 2001 SEPA (unfiltered)	Nov 2001 BGS (filtered)	Mar 2002 SEPA (unfiltered)
59	Orkie Farm, Main Borehole	4.8	13.3	14.7
60	Orkie Farm, Borehole 2	6.9	39.9	33.9
61	St Andrews Golf Links BH2	0.4	0.9	0.7
62	Bowhouse Farm (Abercrombie Farm)	0.4	0.9	0.7
63	Easter Grangemuir Farm	0.4	1.3	
64	Inch Farm	0.4	0.9	0.7
65	Pilmuir Farm	27.1	34.1	32.9
66	Bankhead Farm	0.4	0.9	0.7
69	Ladybank Golf Club	13.7	12.4	
71	Loch Leven Mills	17.4	22.2	22.4
75	St Michaels Golf Course	77.1	81.1	81.9
76	Wormit Farm (Farmers: J & D Henderson)	77.1	94.8	94.3
77	Newton Hill Farm	22.6	23.5	151.8
78	WCF Farm Produce	28.0	27.0	26.7
79	Balmanno Farm	0.4	0.9	0.7
80	Star Inn Farm	24.6	24.8	29.0
82	Logie House	16.3	14.6	14.6
83	Pluckerston Farm	14.7		
84	Mains of Errol	36.0	66.0	41.3
87	Castleton of Eassie Farm	6.8	5.8	6.7
88	Scones of Lethendy	5.6	4.0	34.8
89	Murrayshall Golf Club	9.5	8.0	9.4
90	Findowrie Farm	44.3	50.5	50.0
91	Coupar Grange Farm	28.8	34.6	
92	Stracathro Hospital	47.8	51.8	49.1
93	Davo Mains Farm	8.4	7.1	8.6
94	Pauls Malt Ltd BH 1	37.5	38.5	34.3
95	Pauls Malt Ltd BH 2	24.0	23.5	32.1